Mapping Gene Campaign's Rice Collection and Predicting Future Adaptation Sites in 2020, 2040 & 2060

A total of 872 rice varieties from the Gene Campaign rice collection from Eastern India were analyzed in the study. The collections in the study were made from the 9 states/UT of Jharkhand, Bihar, Odisha, Chhattisgarh, Dadra and Nagar Haveli, Uttar Pradesh, West Bengal, Meghalaya and Assam with the maximum collection concentrated Jharkhand. In order to assign geographic coordinates to the rice collection, various external sources were consulted including the administrative database of the Survey of India and Google Earth. The rice collection database has location information including village, taluka/block, district and state. The location names were searched in the external sources and matching locations were noted at the village level where available in a table. Subsequently, the table with the geographic coordinates with location names was joined with the table listing the rice collection in the ESRI ArcInfo 10.0 software to assign geographic coordinates to the rice collection.

Fig 1 below shows the number of collections from the different districts of the above-mentioned states.
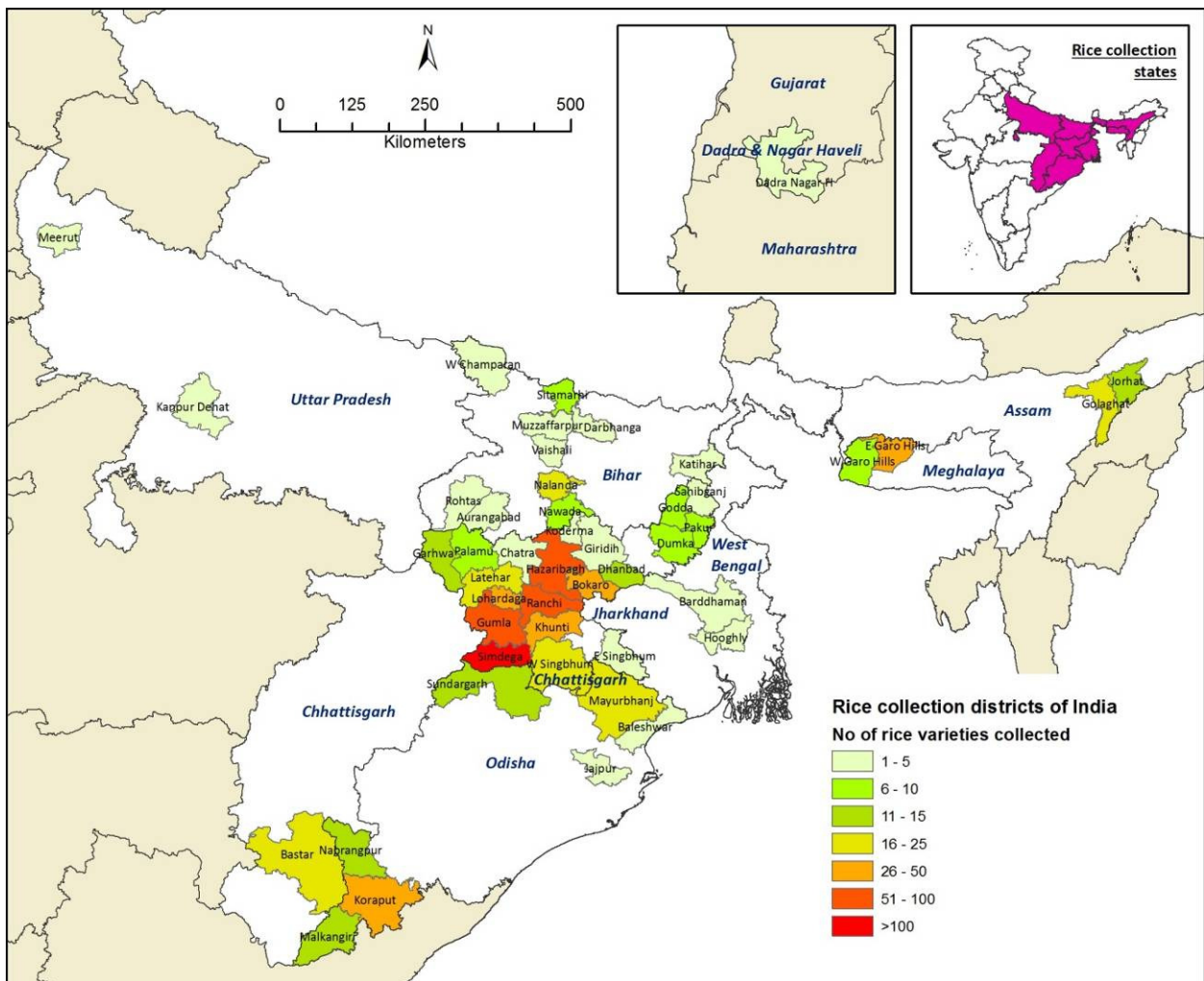

Figure 1: Map showing districts from where rice varieties' seed collected and number of rice varieties

Table 1 shows the districts from which at least 10 rice varieties have been collected

State	District	No of varieties
Jharkhand	Simdega	117
Jharkhand	Ranchi	103
Jharkhand	Hazaribagh	86
Jharkhand	Gumla	82
Odisha	Koraput	40
Jharkhand	Khunti	37
Jharkhand	Lohardaga	36
Jharkhand	Bokaro	31
Meghalaya	East Garo Hill	27
Chhattisgarh	Bastar	25
Assam	Golaghat	21
Jharkhand	Latehar	20
Jharkhand	West Singhbhum	18
Bihar	Nalanda	16
Odisha	Mayurbhanj	16
Jharkhand	Dhanbad	13
Odisha	Malkangiri	13
Odisha	Sundargarh	13
Assam	Jorhat	12
Odisha	Nabrangpur	12
Jharkhand	Garhwa	11
Bihar	Nawada	10

Climate classification for the rice collection

The current climate data from the Worldclim database (http://www.worldclim.org/) (2.5 minutes) for each climatic variable for all the geo-referenced accessions were extracted using DIVA-GIS. The extracted climate data was then grouped into 6 classes for better visual representation and the annual mean temperature and annual precipitation histograms are shown below from Figures 2 to 5. It should be noted here that the figures above the bars show the number of spatially non-duplicate accessions within that class.
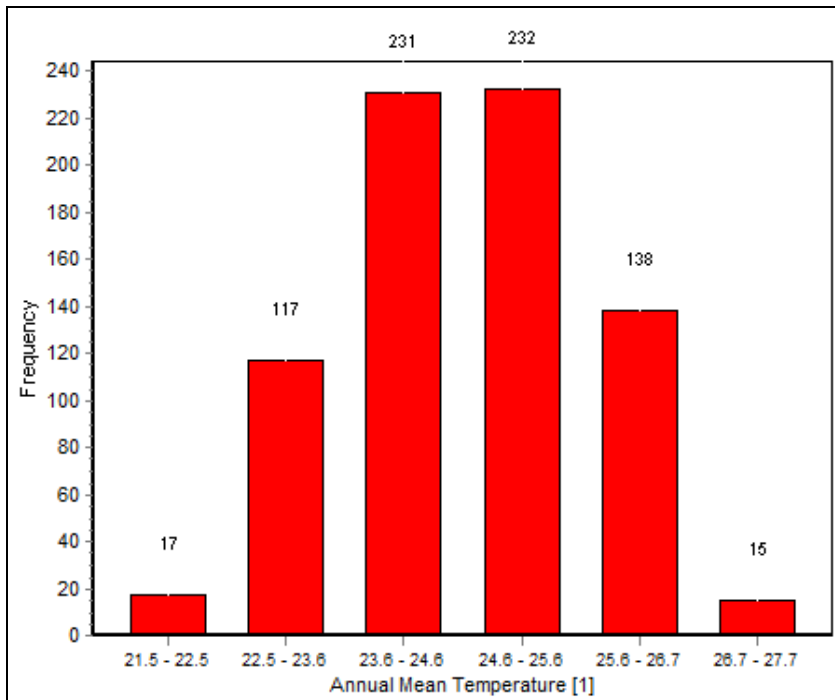

Figure 2: No. of rice accessions from different annual mean temperature classes

It can be seen from Figure 2 that the annual mean temperature for the entire collection of rice accessions falls within the range of 21.5°C to 27.7°C with most of the accessions (61.7%) lying within the range of 23.6-25.6°C. Figure 3 shows the distribution of collection for the mean maximum temperature classes with most accessions (80%) of the collection experiencing a high maximum temperature of greater than 37.6°C while Figure 4 shows that a high percentage (78.5%) of the accessions are from areas experiencing mean minimum temperature between 8.5-11.6°C.
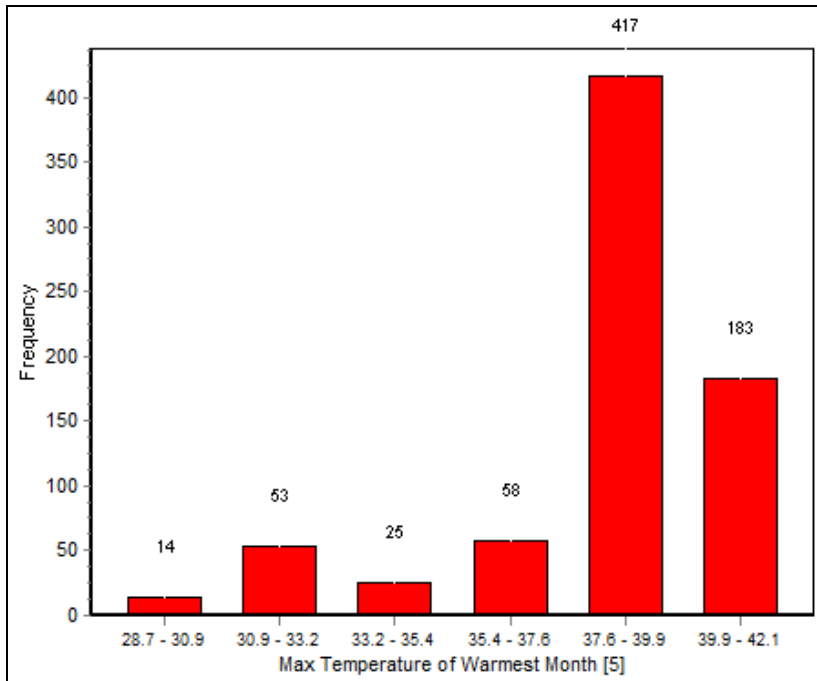
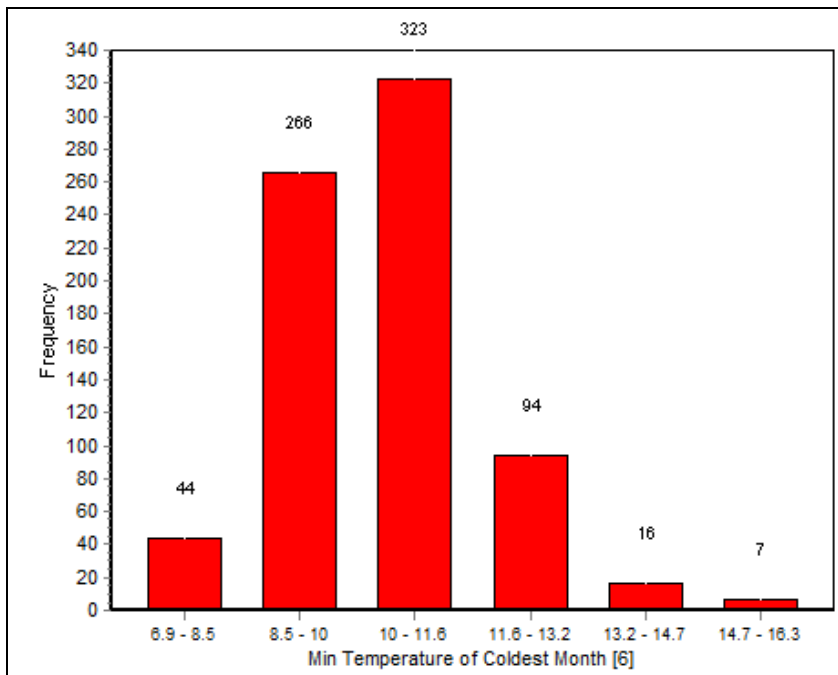**Figure 3: No. of rice accessions from different mean maximum temperature classes**

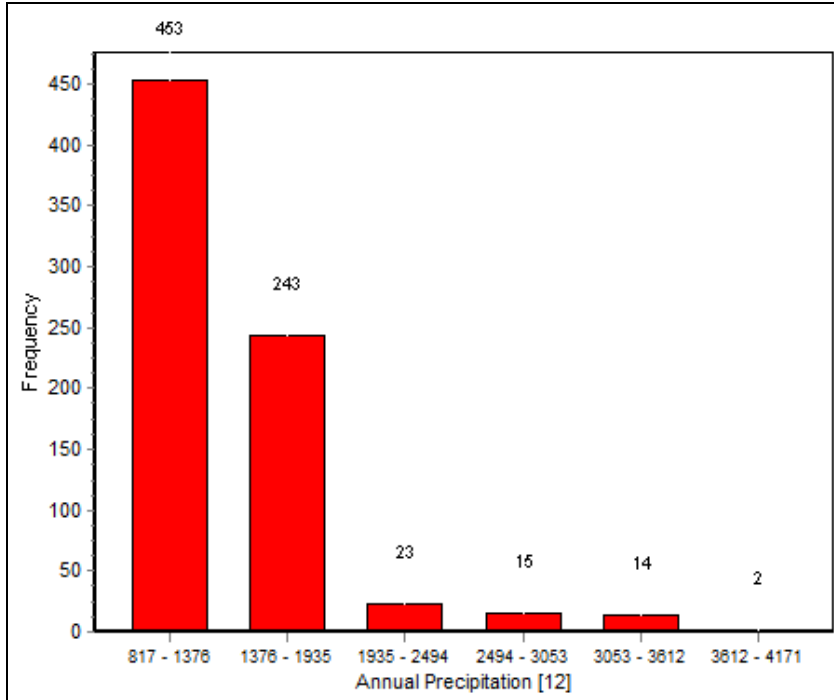**Figure 4: No. of rice accessions from different mean minimum temperature classes**

Figure 5: No. of rice accessions from different annual precipitation classes

Figure 5 shows the distribution of collection locations for annual precipitation. Around 80% of the collection comes from the moderate rainfall areas where the annual precipitation is around 1000-2000 mm. The rest are from areas with heavy rainfall with 16 accessions from areas with annual precipitation higher than 3050 mm.

In order to identify the accessions which are adapted to unique climate conditions, the current annual mean temperature (^{o}C) and annual precipitation (mm) were plotted in DIVA-GIS and the accessions lying outside the envelope shows the unique accessions within the collection (Figure 6). The total collection has also been mapped on Figure 7.

750 observations with 691 (92.1%) in this envelope; (582 (77.6%) overall)
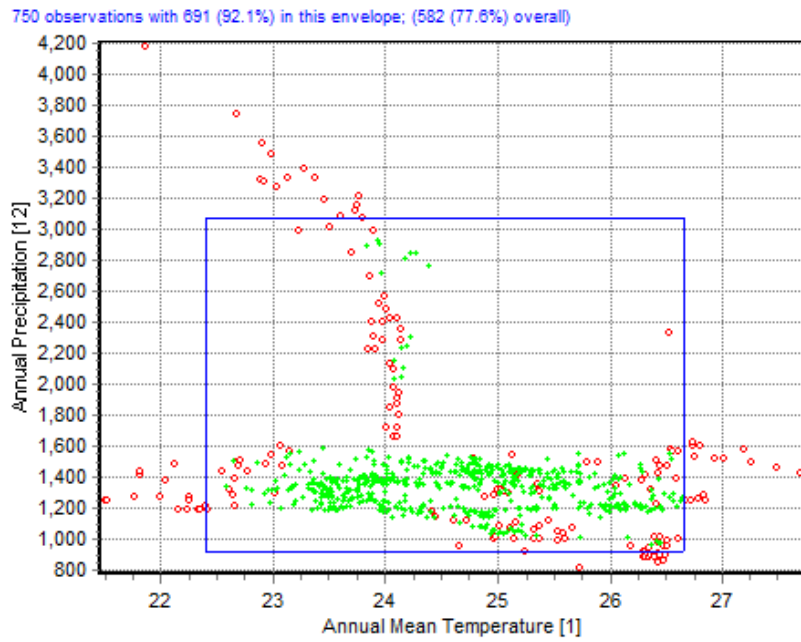
Figure 6: Distribution of accessions based on annual mean temperature and annual mean precipitation
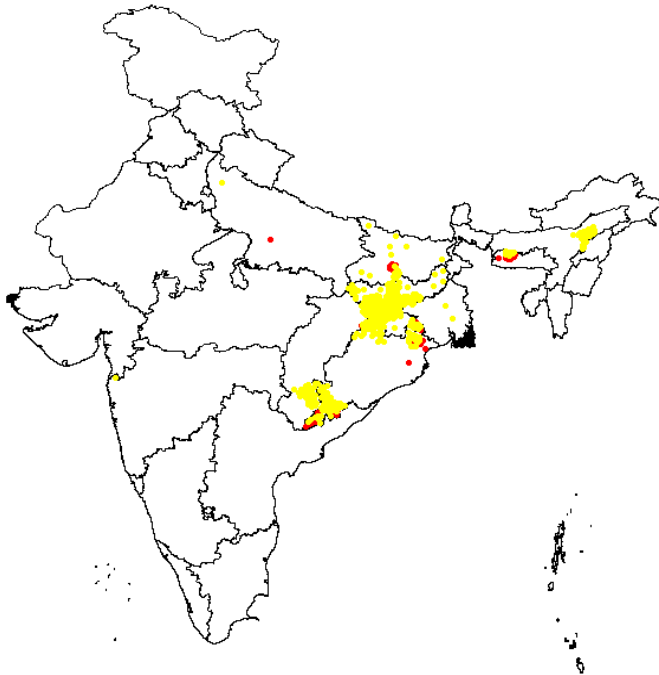
Figure 7: Accessions lying outside the envelope (red) and within the envelope (yellow) as per the distribution modeling of Fig. 6

Understanding the degree to which the rice collection can help farmers cope with climate change

In order to understand which promising collections will be of most use to farmers under predicted changing climate scenarios, it is necessary to identify areas which are vulnerable to climate change and cross reference them with the attributes of the collections available from those sites, either for replication purposes elsewhere or for re-collection purposes. Fig 8 shows the current and future scenarios for mean temperature (a, b and c) and mean precipitation (d, e and f) for the *Kharif* rice growing season (April to October) in India. The climate data for precipitation, mean temperature, maximum temperature and minimum temperature for India were obtained from the Worldclim climate database for current climate and the CSIRO -Mk3.5 General Circulation Model (GCM) SRES A1B of the CSIRO Atmospheric Research Group of Australia was used for the future data for the decades of 2020s and 2040s. The downscaled climate data was then mapped in ArcInfo 10.0 to obtain the information depicted in Figure 8.
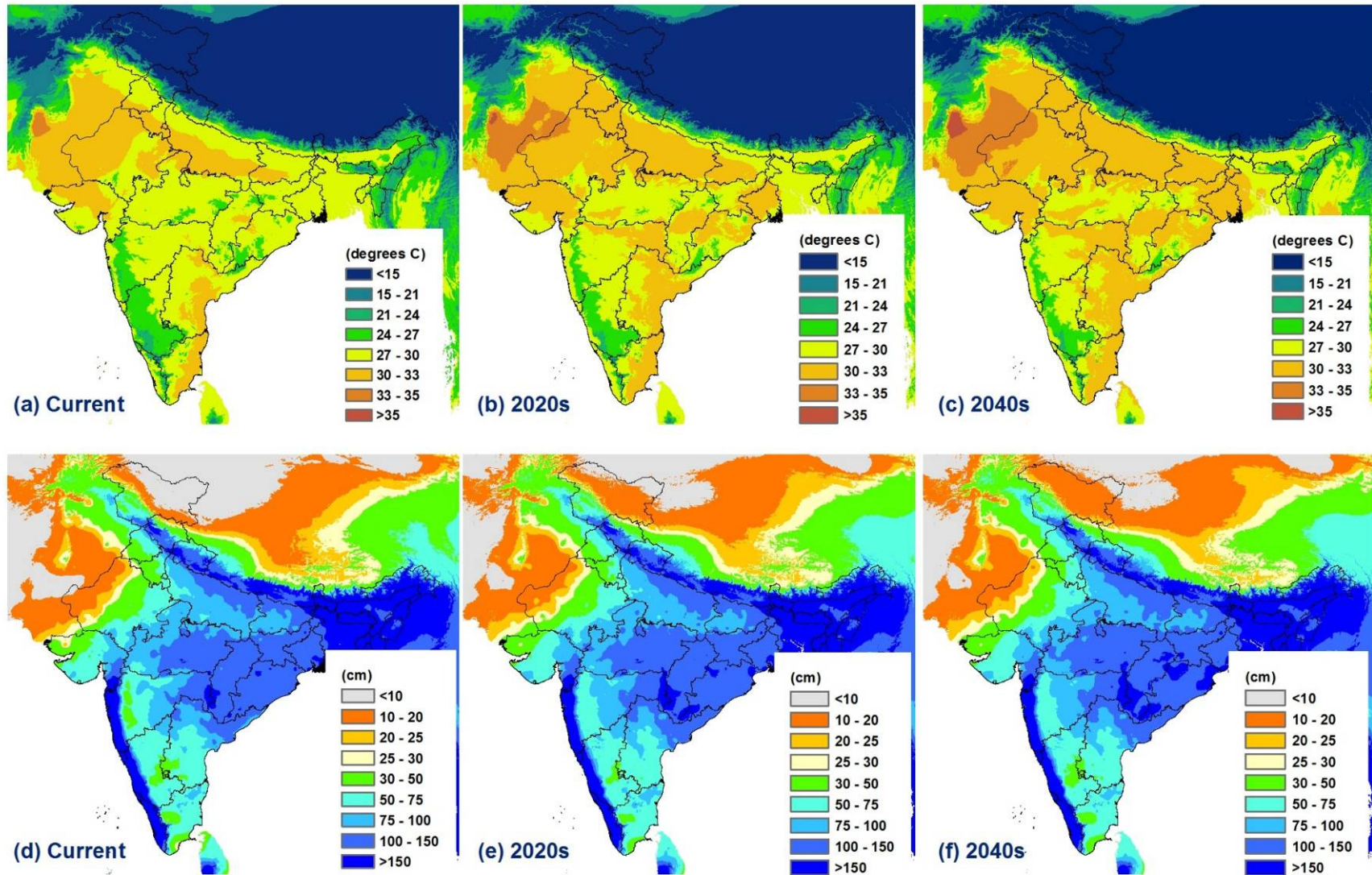
Figure 8: Mean temperature for (a) current, (b) 2020s and (c) 2040s and mean precipitation for (a) current, (b) 2020s and (c) 2040s for April to October

As can be seen from the map, areas along Bihar, Jharkhand, Chhattisgarh and Odisha shows a marked change in temperature while areas where the states of Bihar, Jharkhand and Chhattisgarh adjoins and southern Chhattisgarh show a change in the precipitation from current to future conditions. Based on the collections available and the vulnerability of the sites to changing temperatures and precipitation in the future decades, a climate matching analysis was run for those districts with greater than 10 collections. The climate matching was done through the Maxent (http://www.cs.princeton.edu/~schapire/maxent/) program for maximum entropy modeling which was developed to model species' geographic distributions based on some environmental variables. Maxent, or Maximum Entropy Species Distribution Modelling, was written by Steven Phillips, Miro Dudik and Rob Schapire, with support from AT&T Labs-Research, Princeton University, and the Center for Biodiversity and Conservation, American Museum of Natural History. The model predicts the probability of the presence of a species based on any given environmental condition. In this case, future climate data was used as the environmental variable on whose basis the probability of the accessions being present in future conditions was determined. The rice collection was grouped into clusters based on the district of collection and the future climate probability matching was done for these clusters using the CSIRO - Mk3.5 (2020s and 2040s) GCM SRES A1B of the CSIRO Atmospheric Research Group of Australia. In some cases, the future climate probability matching was also done for 2060s using same climate data from CSIRO. The matching sites will give an indication of similar climatic conditions between two sites such that varieties already adapted to the source site can be tested in the future-matching site or vice versa as part of the adaptation process. The results of a few representative districts are presented below.

Chhattisgarh
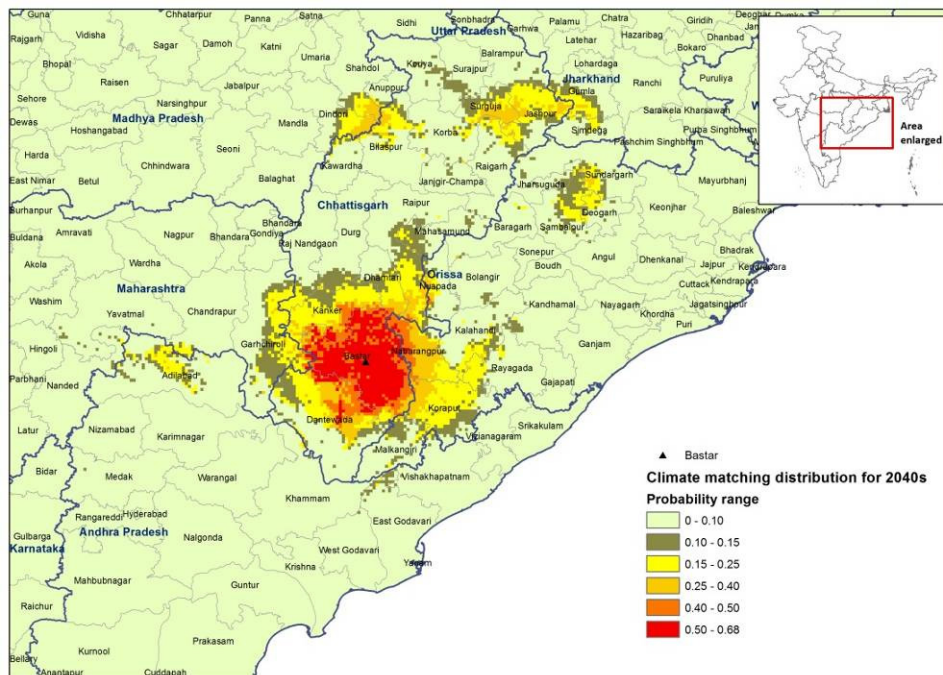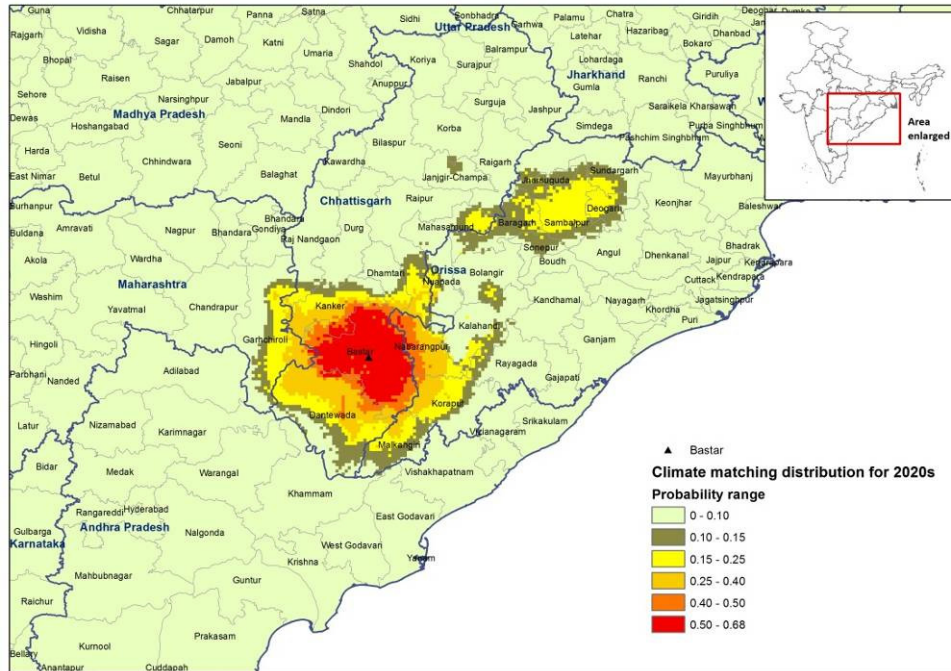
Analysis was run for climate matching sites in the Bastar district. Maximum probability of matching was calculated at 68% for both 2020s and 2040s. Areas in southern Odisha that adjoin the Bastar district, northern Chhattisgarh and few parts of north-western Odisha show medium to low probability matching. Varieties collected from Bastar (25 varieties) that have complementary traits can be tested in these new sites.
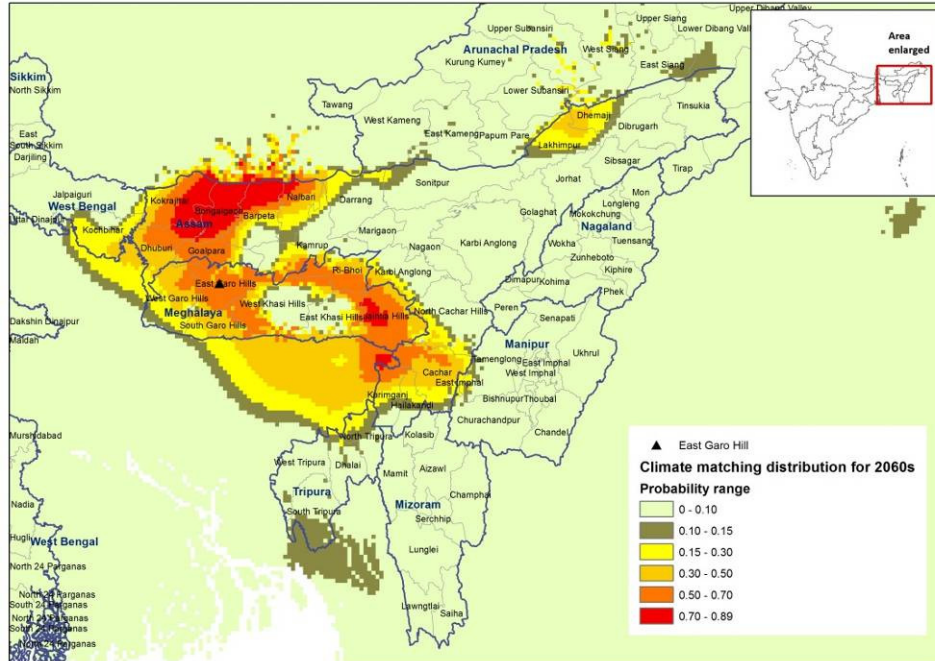
Assam
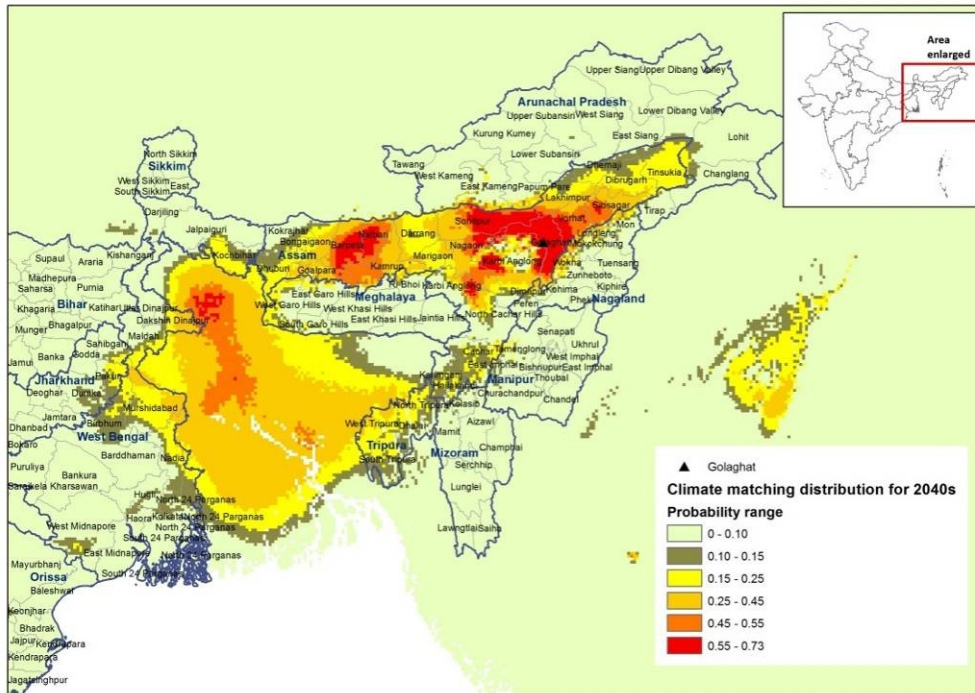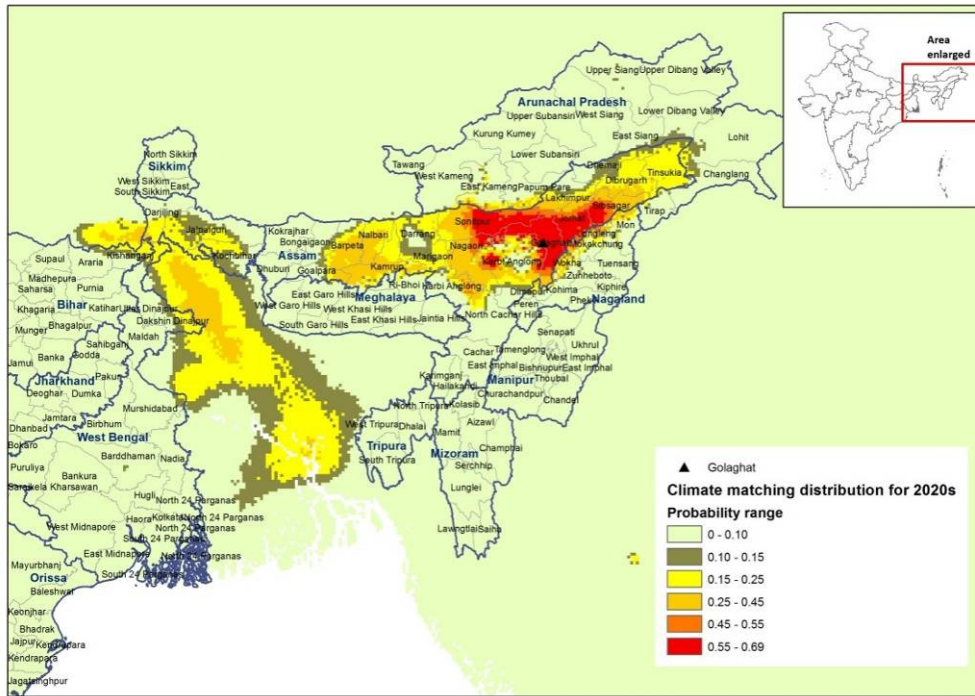
Golaghat district in Assam shows probable climate matching area in northern West Bengal and western Assam. Twenty one rice varieties have been collected from these sites and selected varieties can be tested in these sites. Moreover, selected varieties from the matching sites can also be tested in Golaghat.
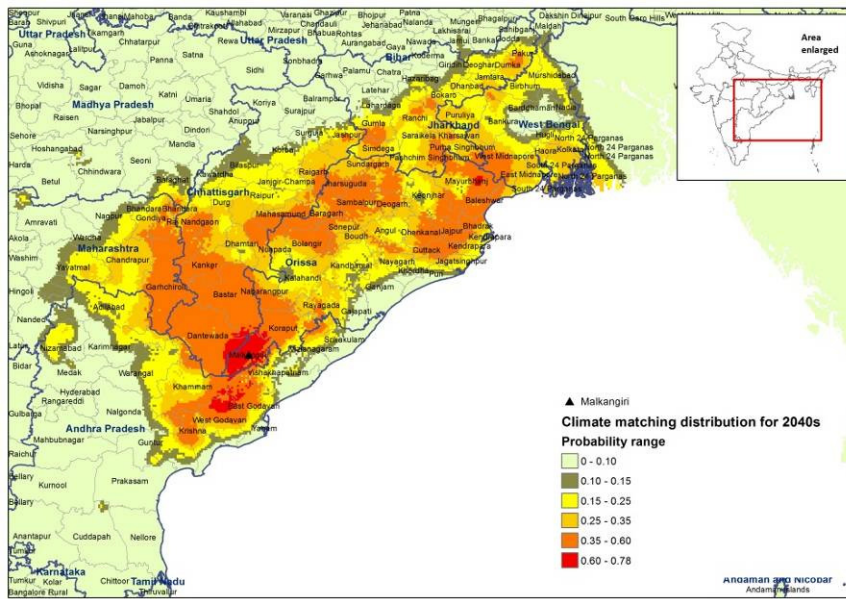
Meghalaya
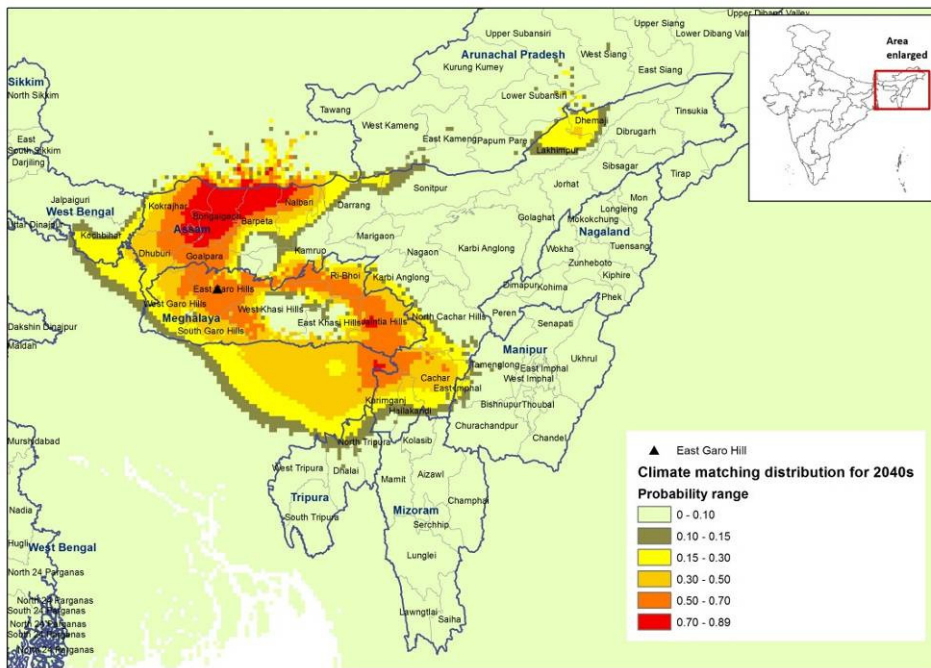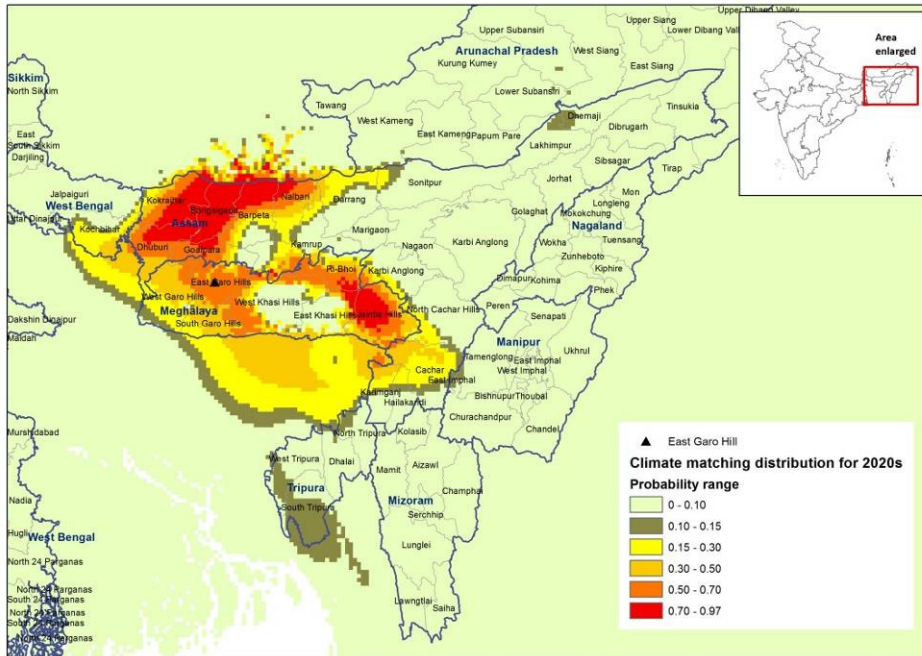
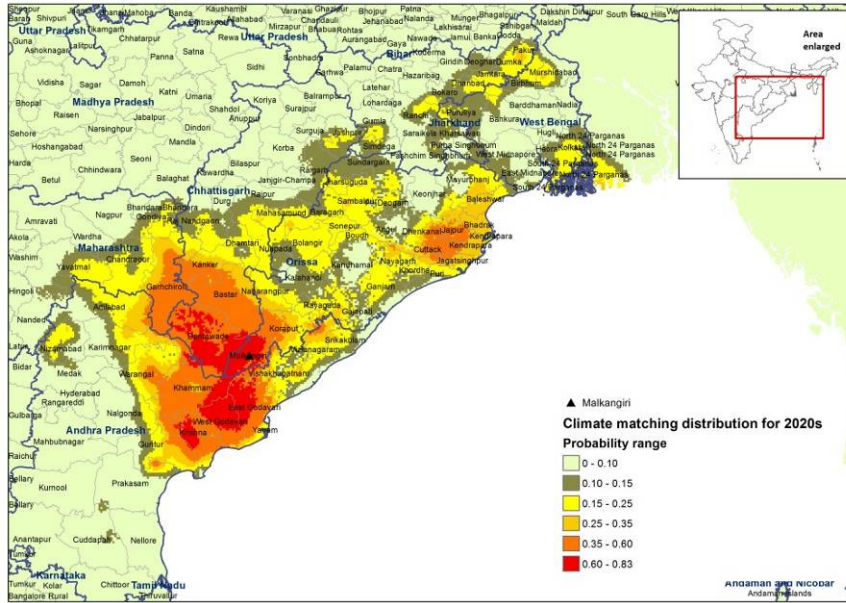The future climate matching analysis of East Garo Hills in Meghalaya shows clearly that most of the highest probability matching sites are shifting north in the 2020s, 2040s and 2060s to areas in western Assam. Some areas in eastern and northern Meghalaya also shows probable matching areas. Twenty seven rice varieties have been collected from East Garo Hill district and can be tested at the matching sites.

Bihar
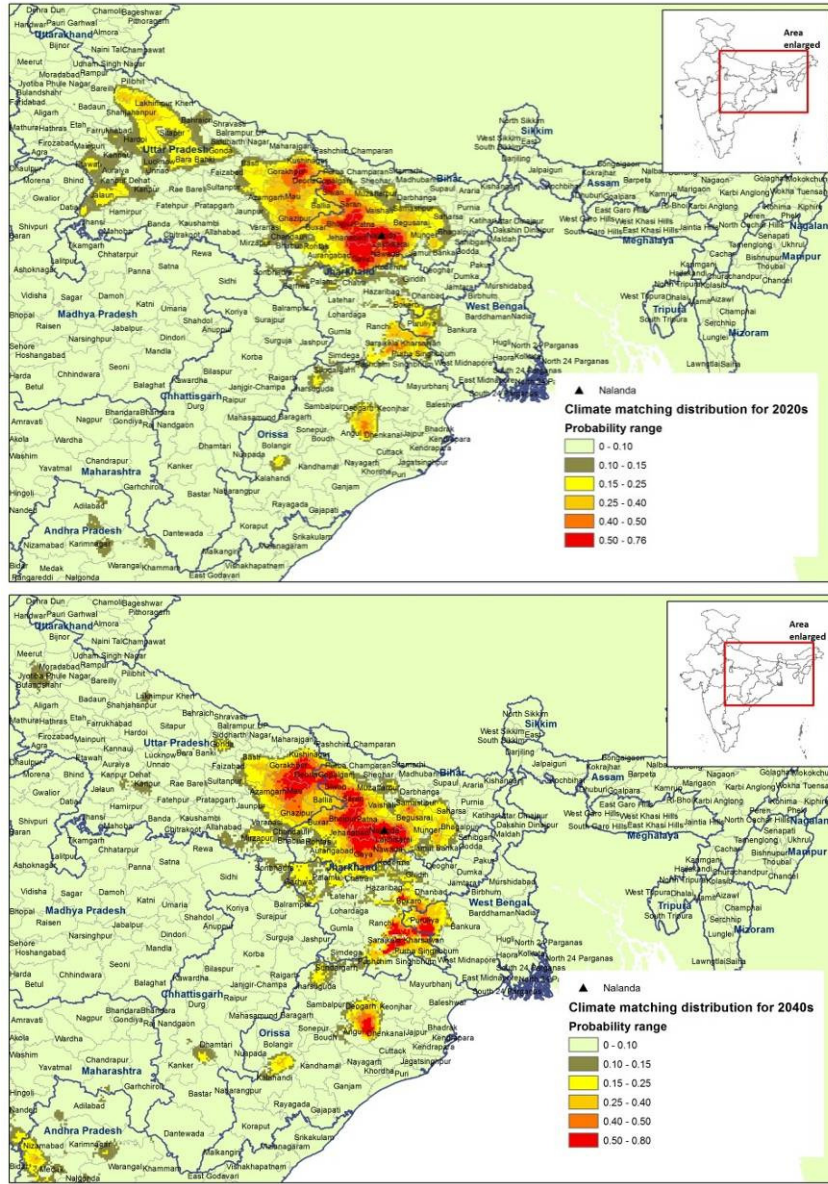
The climate matching analysis of Nalanda district in Bihar shows probable matching areas west of the district and low probability matching sites in the central Uttar Pradesh region in the 2020s while matching areas can be found in the eastern Jharkhand – south-western West Bengal contiguous region and central Odisha in the 2040s. Sixteen rice varieties have been collected from Nalanda district and can be tested at the matching sites.

Odisha

▲ Malkangiri
Climate matching distribution for 2020s
Probability range
- 0 - 0.10
- 0.10 - 0.15
- 0.15 - 0.25
- 0.25 - 0.35
- 0.35 - 0.60
- 0.60 - 0.83

▲ Malkangiri
Climate matching distribution for 2040s
Probability range
- 0 - 0.10
- 0.10 - 0.15
- 0.15 - 0.25
- 0.25 - 0.35
- 0.35 - 0.60
- 0.60 - 0.78

Climate matching distribution for 2060s
Probability range
- 0 - 0.10
- 0.10 - 0.15
- 0.15 - 0.25
- 0.25 - 0.35
- 0.35 - 0.60
- 0.60 - 0.78
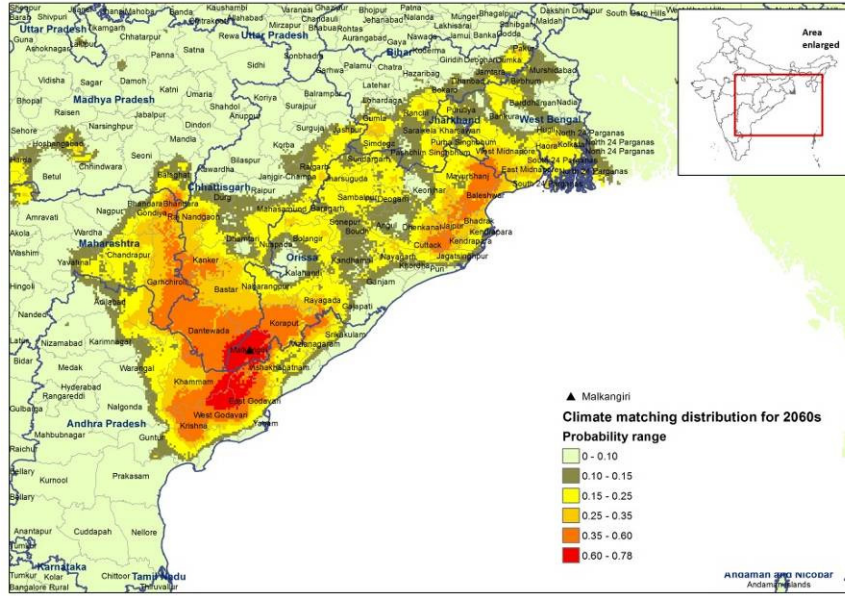
▲ Malkangiri

The climate matching analysis of Malkangiri district in Odisha shows that a wide stretch of area covering Odisha, Chhattisgarh, Jharkhand, West Bengal and some parts of Maharashtra and Andhra Pradesh have high to low probability. While the climate matching areas do not differ much from the 2020s, 2040s and 2060s, it can be seen that the highly probable areas (>60%) are reducing considerably. Thirteen rice varieties have been collected from Malkangiri district and can be tested at the matching sites.

Jharkhand
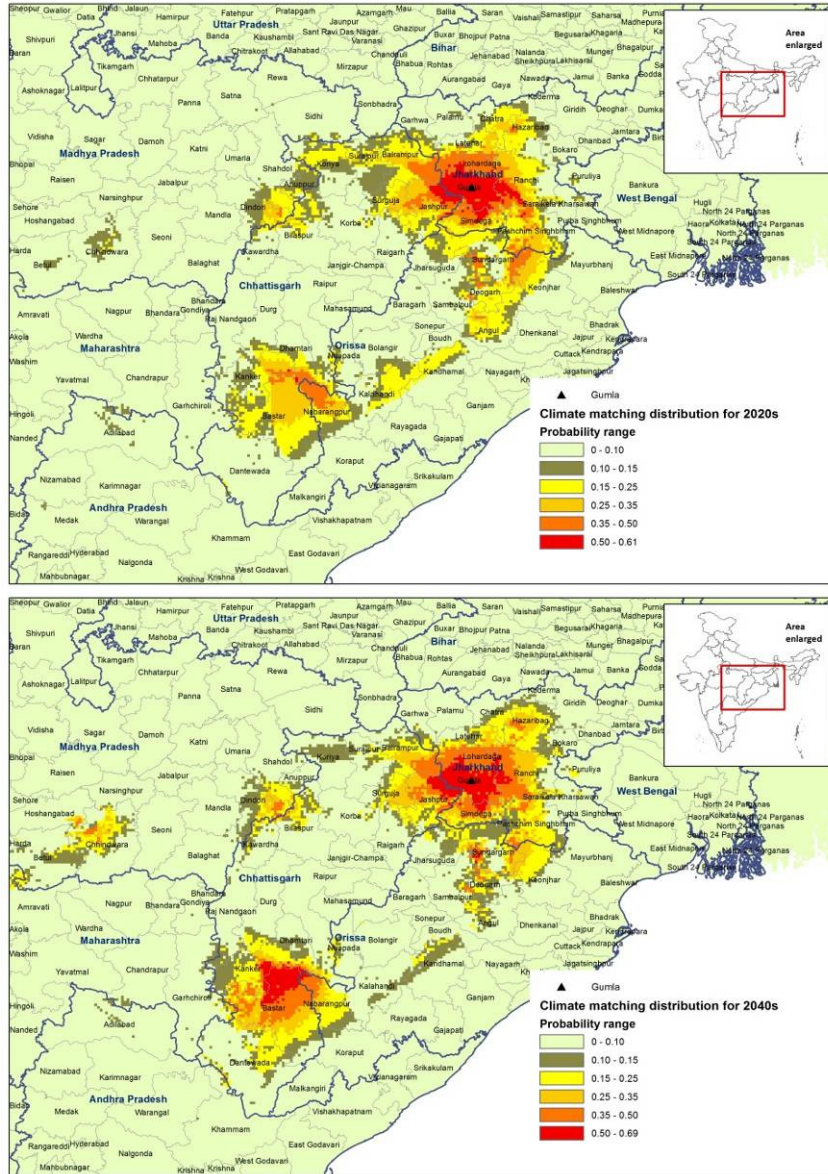
The climate matching analysis of Gumla district in Jharkhand shows probable matching areas in Jharkhand, northern and southern Chhattisgarh and some parts of northern and central Odisha. Some areas of southern Madhya Pradesh also shows increasing match from the 2020s to 2040s probably as a result of increasing precipitation predicted for these sites in the future (see Fig 2-d,e,f). Eighty two rice varieties have been collected from Gumla district and can be tested at the matching sites.

Climate matching distribution for 2020s

Climate matching distribution for 2040s
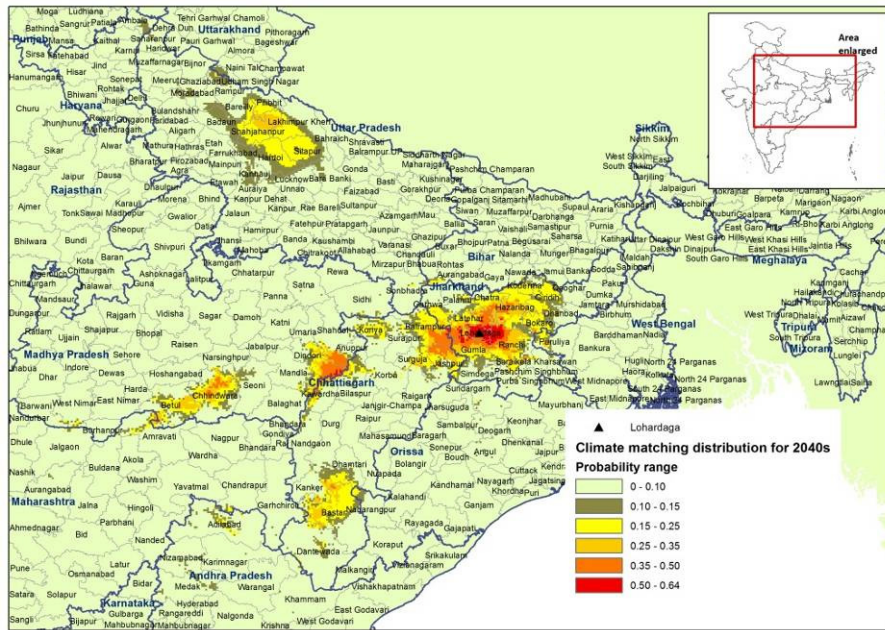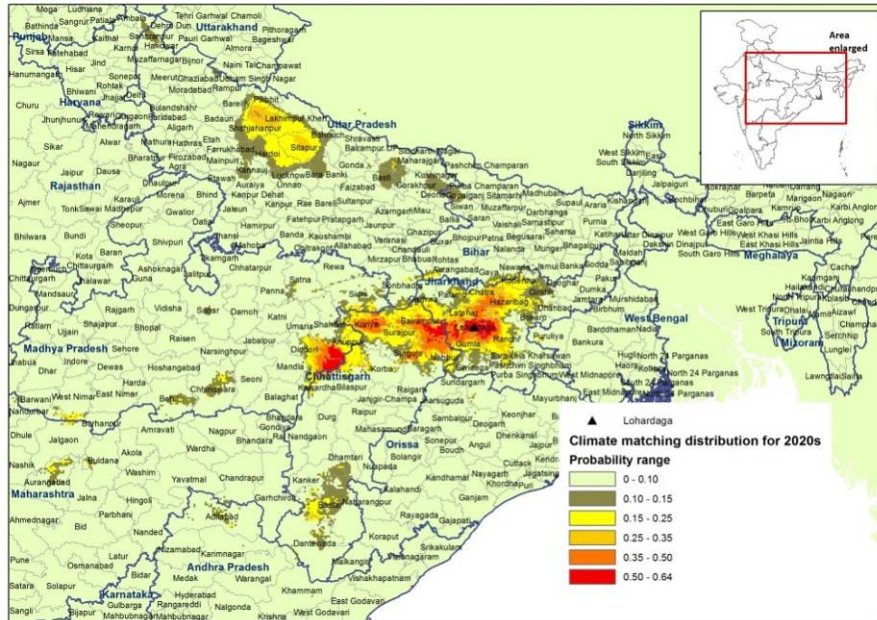
The climate matching analysis of Lohardaga district in Jharkhand shows probable matching areas in Jharkhand, southern Chhattisgarh, eastern and southern Madhya Pradesh and some parts of central Uttar Pradesh. Thirty six rice varieties have been collected from Gumla district and can be tested at the matching sites.

References:

Steven J. Phillips, Miroslav Dudík, and Robert E. Schapire. 2004. A maximum entropy approach to species distribution modeling. In Proceedings of the Twenty-First International Conference on Machine Learning, pages 655-662

Steven J. Phillips, Robert P. Anderson, Robert E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling, Vol. 190, pages 231-259

Jane Elith, Steven J. Phillips, Trevor Hastie, Miroslav Dudík, Yung En Chee, Colin J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions, Vol. 17, pages 43-57